Influence of Packaging on Postharvest Quality of Strawberry Fruit

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Abstract

In Pakistan, strawberry is among the most delicious fruits. It is grown all over the world due to its nutritional value, but it faces high fungal attacks and rapid respiration. The main problem with strawberry fruit is that it has a low shelf-life and is prone to rapid decay. Poor packaging material is the main cause that deteriorates the quality and reduces the shelf life of strawberry. However the postharvest quality of strawberry (*Fragaria x ananassa*) can be enhanced by modifying its packaging. The purpose of this study is to assess the effect of conventional and improved packaging material which can increase the postharvest quality of strawberry. Effect of four types of packaging materials (8 kg plastic basket, 8 kg plastic crate, 4 kg plastic crate or 360 g plastic punnet) was analysed. Fruits were harvested and immediately packed and stored at room temperature for maximum 4 days. The results indicated that 360 g plastic punnet showed maximum marketable fruit weight percentage (85%), color hue angle (6), total soluble solids (TSS) (11.87 Brixº), fruit ripening index (71.67), ascorbic acid content (202.63 mg 100 g^{-1}), dry weight percentage (4.24 %), ion leakage (36.3 %) and reducing and non-reducing sugars (2.43%, 3.85%), and less disease, decay, damage incidence with minimum fruit weight loss by applying the Completely Randomized Design.

Keywords: Nutritional value, fungal attack, respiration, shelf life, packaging, postharvest quality, biochemical and physical characters.

Introduction

Strawberry (*Fragaria x ananassa*) is an important member of the family Rosaceae. It is an aggregate fruit because receptacles are involved in the formation of its fleshy part and ovaries do not contribute to this process. Various extremely small fruits are present on the flesh of strawberry fruit called achenes. Achenes are white to brown colored and have seeds in them. In Pakistan strawberry is grown on an area of 171 hectares with an annual production is 591 tonnes. As strawberry is low in calories and a great source of vitamin C, fibers, ascorbic acid, and potassium folate, it is highly nutritious and consumed as fresh and processed. Researchers claim that strawberry contains low amounts of sugar and plays a potential role in improving memory power and reducing the danger of cancer and heart diseases.

Fruit development and ripening occur rapidly, and its delicate texture makes it a "soft fruit". Texture, flavor and color are strongly affected by lots of physiological changes that makes the fruit vulnerable to microbial attack and lower its shelf life (Perkins-Veazie, 1995). Microbial mould and high metabolic action reduce the postharvest life of strawberries and raspberries (Brown *et al.*, 1984; Joles *et al.*, 1994). Strawberry is categorised as fruits with very short shelf life (Zafa et al., 2023: Perez *et al.*, 1998). Apart from shelf life, research efforts are also underway to add values related to nutrition. For this purpose, the packaging atmosphere is modified in such a way that CO_2 level is increased and O_2 level is decreased which shows very good effects on the storage of strawberry. Fruit decay can be efficiently controlled by storing fruits in cold conditions in which 10% to 20% of CO_2 is maintained (Ceponis *et al.*, 1983; Li *et al.*, 1989; Gil *et al.*, 1997; Shen *et al.*, 2003).

In the postharvest phases, strawberries metabolize quickly which is influenced by various factors. Harvesting at optimum maturity, lower automated injuries, favorable temperature and relative humidity during marketing are the primary factors which effects shelf life and quality of strawberries (Lipton, 1977; Bohling and Hansen, 1980; Kader *et al.*, 1989). The modified atmosphere which is generally referred as MA acts as a secondary factor (Syed *et al.*, 2022: Burton, 1974; Kader, 1986). 35% to 40% of fruits and vegetables are lost in Pakistan as postharvest losses. During postharvest storage most of the microbial degradation caused by two most fungus species *Botrytis cinerea* and *Rhizopus* sp. (Tariq *et al.*, 2022: Mass 1981). Rhizopus sp. mostly attack near to the ripening stage. Various researches have been conducted on modified atmosphere packaging and it has been indicated that uniformity of cooling process and its rate is controlled by efficient packaging design ad this packaging also affect its behaviour with local air flow (Edmond *et al.*, 1996; Vigneault and Goyette, 2002; Anderson *et al.*, 2004; Castro *et al.*, 2004; Talbot, 1988; Xu and Burfoot, 1999; Hoang *et al.*, 2001, 2003; van der Sman, 2002; Tanner *et al.*, 2002; Alvarez *et al.*, 2003; Zou *et al.*, 2006: Akbar *et al.*, 2022).

Active packaging is mostly used these days and referred to as a better technique of food packaging which prolongs the shelf life and maximizes the sensory and safety attributes, maintaining the product quality (Suppakul *et al.*, 2003: Asif *et al.*, 2023). Absorbent packaging comprises of setting armours in the packaging systems (Guynot *et al.*, 2003: Afzal *et al.*, 2023), with the proper regulation of carbon dioxide, oxygen and moisture controlling systems. (Suppakul *et al.*, 2003: Abbas *et al.*, 2022). Climate, packaging material, harvest and maturity are very essential agents that affect the postharvest life of the strawberry. Strawberries must be stored under conditions that prevents it from physiological effects which could damage the fruits (Ullah *et al.*, 2023: Rooney, 2000; Zagory, 1997). Temperature must be taken into account while designing the packaging system for strawberry. The activation energy value for the O_2 is 38 $kJ.mol^{-1}$ in the film material that has low-density polyethylene (LDPE). Permeation of different gases through the packaging is very sensitive and has very low activation energy that is equal to 4.3 $kJ.mol^{-1}$ (Riaz *et al.*, 2022: Cameron *et al.*, 1994).

Materials and Methods

Fruit Treatments

In current experiment, influence of different packaging materials on postharvest quality and shelf life of strawberry was studied. The research was carried out at the Institute of Horticultural Sciences, University of Agriculture Faisalabad. Strawberry fruits (*Fragaria* x *ananassa*) were harvested from a commercial farm with coordinates near Sharakpur, District Sheikhupura, Punjab, Pakistan and the fruits were at full maturity level. Strawberry fruits were packed in four types of packing material i.e., 8 kg plastic basket, 8 kg plastic crate, 4 kg plastic crate, and 360 g plastic punnet. Strawberries were packed and immediately stored at room temperature. The fruits were categorised into marketable and non-marketable fruits which were analysed under several parameters such as fruit colour, size, weight and microbial attack of fruits.

Fruit Weight

Five fruits from each packaging were randomly weighed with the digital weighing balance (MJ-WJ176P, Panasonic Japan).

Disease Incidence

Disease, damage and decay incidence is measured by scale devised by Fischer *et al.* (1992) and Babalar *et al.* (2007) was used for strawberries.

Fruit Weight loss

For fruit weight loss percentage five fruits from each packaging were randomly selected and their weight was recorded by individually keeping fruits on the digital weighing balance (MJ-WJ176P, Panasonic Japan) and their percentages were calculated.

Dry Matter Percentage

For dry weight, randomly 3 to 4 fruits were selected and cut down in small segments. After cutting, fruits were dried at 60^{o}C in hot air drier for almost one day. After one day, total moisture was lost, and fruit dry weight was recorded. This dry weight was recorded with the digital weighing balance (MJ-W176P, Panasonic Japan).

Fruit Peel Colour

Fruit peel colour was recorded with handheld digital Colour Analyzer (Minolta, USA).

Electrolyte Leakage

For ion leakage, about 20 mL of distilled water was taken in 100 mL beaker and small pieces of strawberry fruit were placed in it. Ion leakage was determined using EC meter (HI 98107, Hanna Instruments, Mauritius).

Total Soluble Solids

For total soluble solids, 15-20 fruit were cut down into small segments and juice was extracted. Then centrifugation was done at 5,000 *xg* for 10 minutes. Total soluble solids were determined from the supernatant by using a digital refractometer (Atago, RX 5000, Japan).

Titratable acids

Titratable acid was calculated by using the method of Hortwitz (1960). Ten milliliters of juice was taken in 100 mL of the beaker and 50 mL of distilled water was added. This dilution was titrated against 0.1 N NaOH, using 2-3 drops of phenolphthalein as an indicator till pink color was achieved.

Ripening Index

Ripening index was computed in each replication by dividing total soluble solids with titratable acid.

Ascorbic Acids

For the estimation of ascorbic acid in the fruit pulp, the method described by Khalid *et al.* (2012) was used. Ten millilitres of juice were taken in 100 mL of volumetric flask and then volume was made 100 mL by the addition of 0.4% oxalic acid. From 100 mL of solution, 5 mL aliquot was taken in a 100 mL beaker after filtration and titration against dye until the light pink colour was achieved which stayed for ten seconds.

Sugars

The filtrate was taken in a 50 mL burette and titrated against 10 mL Fehling solution with constant boiling on delicate fire until brick red colour showed up. The 2-3 drops of 1% methylene blue were added and titration was continued by adding the aliquot dropwise into boiling solution until brick red colour was produced once again. The used amount of aliquot was recorded and reducing sugars were ascertained using equation, reducing sugars (%) = 6.25 (X/Y), where X is the volume of standard sugar used against 10 mL of Fehling solution and Y is the volume of sample aliquot used against 10 mL of Fehling solution. The 25 mL of aliquot was taken from the filtrate in a 100 mL of volumetric flask and after that 20 mL of distilled water and 5 mL of concentrated HCl was added in it. The solution was kept for 24 hours for the complete conversion of non-reducing sugars into reducing sugars. Next day, it was neutralized by adding 5 mL of 40 g NaOH per 100 mL using phenolphthalein as an indicator and volume was made up to the mark with distilled water. This solution was taken into the 50 mL burette and titrated against 10 mL Fehling solution for the estimation of total sugars i.e., Total sugars (%) = 25(X/Z), where X is the volume of standard sugar used against 10 mL of Fehling solution, and Z is the volume of aliquot titrated against 10 mL of Fehling solution. Percentage of non-reducing sugars was estimated using equation, 0.95 x (total sugar percentage – reducing sugar percentage).

Statistical Design

The data was evaluated using Completely Randomized Design (CRD) with two factors (jujube treatments and storage days). The collected data were analyzed statistically using STATISTIX 8.1®, and means were compared with Least Significant Test (LSD, $p \leq .05$).

Results and Discussion

The study was carried out to check out the effect of different packaging materials on the postharvest quality and shelf life of strawberry. The fruits packed in 360 g plastic punnet showed maximum marketable fruit weight percentage. While the fruit bulk weight in 8 kg plastic basket and 8 kg plastic crate is 75 kg and 75.67 kg and 4 kg plastic crate weigh 82.34 Kg and 360 g plastic punnet is 85 kg. The minimum average marketable weight percentage was recorded in 8 kg plastic crate on third day, but the maximum average marketable fruit weight percentage is recorded in 8 kg plastic basket and 360 g plastic punnet on the very first day. Disease incidence in 8 kg plastic basket is recorded as 2.33, in 8 kg plastic crate is 2, in 4 kg plastic crate is 2.33 and 360 g plastic punnet is 2. While, the minimum average unmarketable fruit disease incidence is recorded in all the packaging materials on the very first day and maximum was recorded in 8 kg plastic basket, 8 kg plastic crate and 4 kg plastic crate on third day of experiment. Decay incidence in 8 kg plastic basket was recorded as 2.66, in 8 kg plastic crate is 2.33, in 4 kg plastic crate is 2 and 360 g plastic punnet is 1.33. The minimum average unmarketable fruit decay incidence in all packaging materials on the very first day and maximum was recorded in 8 kg plastic basket on third day of experiment, while 360 g showed minimum unmarketable fruit decay incidence.

Damage incidence in 8 kg plastic basket is 3, in 8 kg plastic crate is 3.33, in 4 kg plastic crate is 2.33 and 360 g plastic punnet is 1.66. Fruit damage incidence was recorded in 8 kg plastic basket, 4 kg plastic crate and 360 g plastic punnet on the very first day and maximum was recorded in 8 kg plastic basket and 8 kg plastic crate on third day of experiment. The total minimum unmarketable fruit damage incidence average was recorded in 360 g plastic punnet. The average of marketable fruit peel colour hue angle was recorded in 8 kg plastic basket is 4, in 8 kg plastic crate is 5, in 4 kg plastic crate is 6 and 360 g plastic punnet is 6. The minimum average marketable fruit peel colour hue angle was recorded in 8 kg plastic basket on the third day and maximum was recorded in 4 kg plastic crate and 360 g plastic punnet on first day of experiment. The total maximum marketable fruit peel colour hue angle average was recorded in 4 kg plastic crate and 360 g plastic punnet.

The average of marketable fruit weight loss was recorded. The minimum average marketable fruit weight loss was recorded in 360 g plastic punnet on the third day and maximum was recorded in 8 kg plastic basket on third day of experiment. The total minimum marketable fruit weight loss average was recorded in 360 g plastic punnet. The average of fruit dry weight percentage was recorded in 8 kg plastic basket is 3.48 g, in 8 kg plastic crate is 3.68 g, in 4 kg plastic crate is 3.85 g and 360 g plastic punnet are 4.24 g. The minimum average fruit dry weight percentage is recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on first day of experiment. The total maximum fruit dry weight percentage average was recorded in 360 g plastic punnet. The average of ion leakage percentage was recorded in 8 kg plastic basket is 23.13, in 8 kg plastic crate is 27.37, in 4 kg plastic crate is 31.36 and 360 g plastic punnet is 36.3. The minimum average ion leakage is recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum ion leakage average was recorded in 360 g plastic punnet.

Fruit total soluble solids (TSS) was recorded in 8 kg plastic basket is 11.52, 8 kg plastic crate was 11.62, 4 kg plastic crate was 11.76 and 360 g plastic punnet was 11.87. The minimum total soluble solids are recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum total soluble solids were recorded in 360 g plastic punnet. The average of titratable acid recorded in 8 kg plastic basket was 0.2, 8 kg plastic crate was 0.19, in 4 kg plastic crate was 0.18 and 360 g plastic punnet was 0.17. The minimum titratable acid is recorded in 360 g plastic punnet on the third day and maximum was recorded 8 kg plastic basket, 4 kg plastic crate on first day of experiment. The total maximum titratable acid was recorded in 8 kg plastic basket. The average of fruit ripening index was recorded in 8 kg plastic basket was 59, in 8 kg plastic crate was 61, in 4 kg plastic crate was 66.67 and 360 g plastic punnet was 71.67. The minimum average fruit ripening index was recorded in 8 kg plastic basket on the first day and the maximum was recorded 360 g plastic punnet on third day of the experiment. The total maximum fruit ripening index was recorded in 360 g plastic punnet.

The average of fruit juice ascorbic acid was recorded in 8 kg plastic basket was 172.64, in 8 kg plastic crate was 184.05, in 4 kg plastic crate was 191.36 and 360 g plastic punnet was 202.63. The minimum average fruit juice ascorbic acid is recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum fruit juice ascorbic acid average was recorded in 360 g plastic punnet. The average of fruit juice reducing sugars was recorded in 8 kg plastic basket was 1.27, 8 kg plastic crate was 2.20, 4 kg plastic crate was 2.83 and 360 g plastic punnet was 2.43. The minimum average fruit juice reducing sugars is recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum fruit juice reducing sugars average was recorded in 360 g plastic punnet. The average of fruit juice non-reducing sugars was recorded in 8 kg plastic basket was 3.24, 8 kg plastic crate was 3.43, 4 kg plastic crate was 3.59 and 360 g plastic punnet was 3.85. The minimum average fruit juice non-reducing sugars are recorded in 8 kg plastic basket on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum fruit juice non-reducing sugars average was recorded in 360 g plastic punnet. The average of fruit juice total sugars was recorded in 8 kg plastic basket is 1.63, 8 kg plastic crate was 1.64, 4 kg plastic crate was 1.65 and 360 g plastic punnet was 1.66. The minimum average fruit juice total sugars are recorded in 8 kg plastic basket and 8 kg plastic crate on the first day and maximum was recorded 360 g plastic punnet on third day of experiment. The total maximum fruit juice total sugars average was recorded in 360 g plastic punnet.

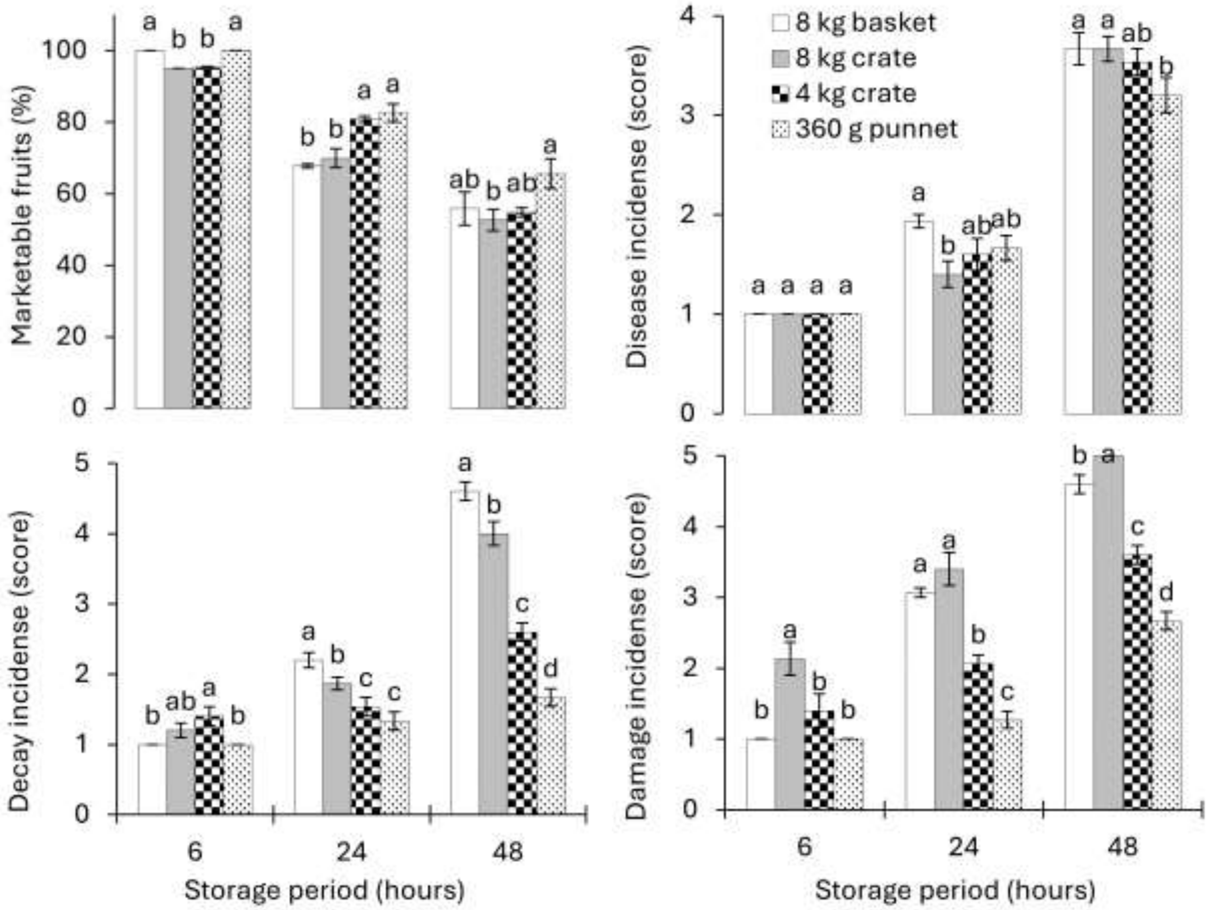

Figure 1: Effect of packaging on marketable fruit percentage, disease incidence, decay incidence and damage incidence. Vertical bars indicate average ± standard error.

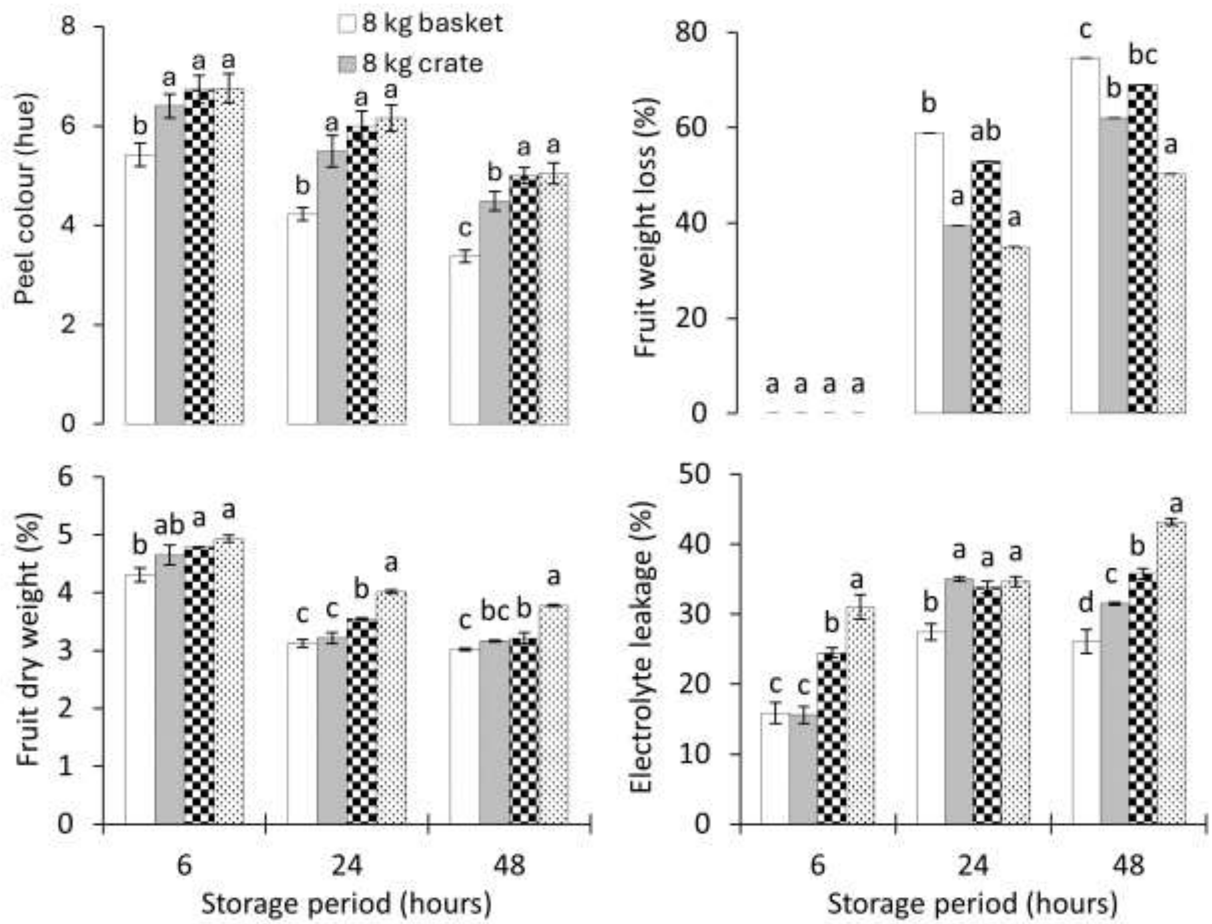

Figure 2: Effect of packaging on peel color, fruit weight loss, fruit dry weight, and electrolyte leakage. Vertical bars indicate average ± standard error.

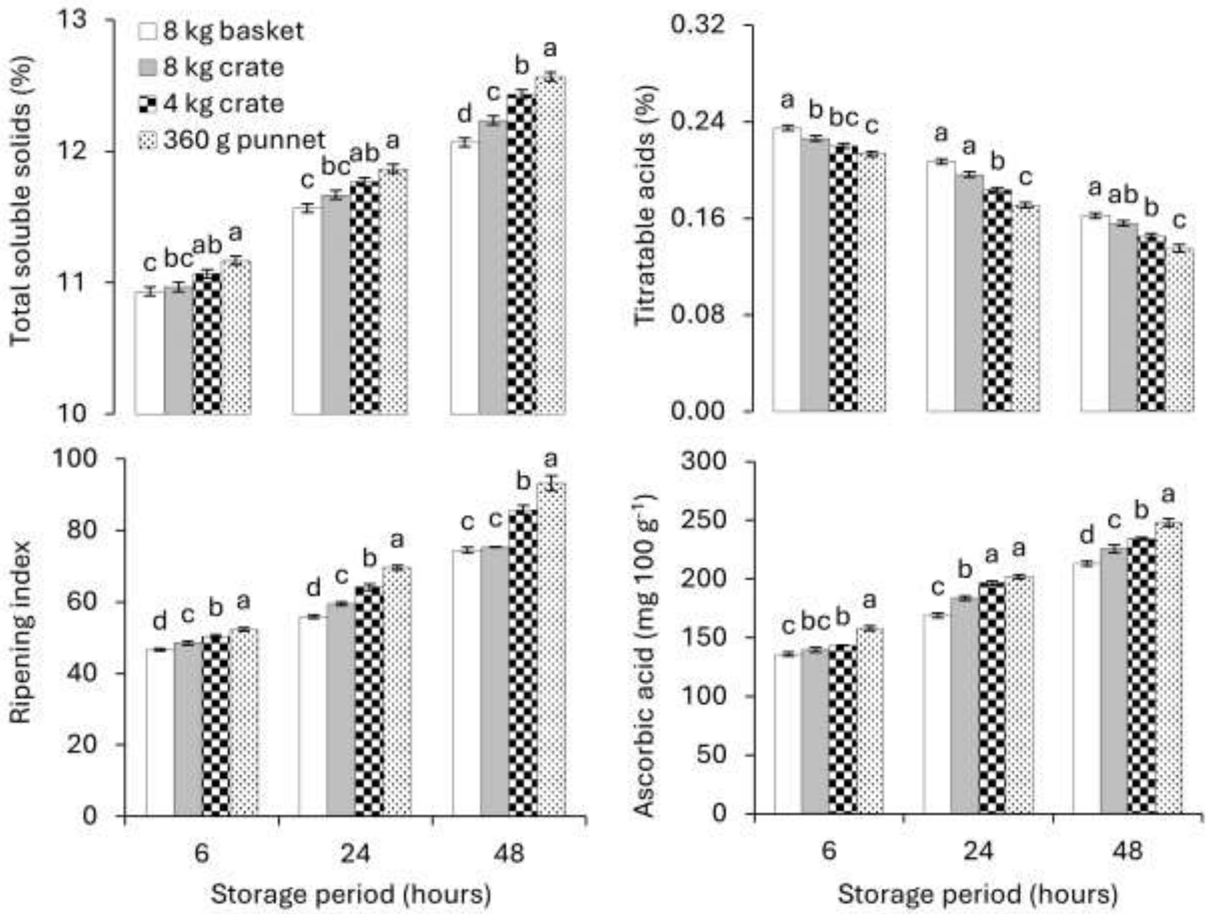

Figure 3: Effect of packaging on total soluble solids, titratable acids, ripening index, and ascorbic acid in strawberry fruit. Vertical bars indicate average ± standard error.

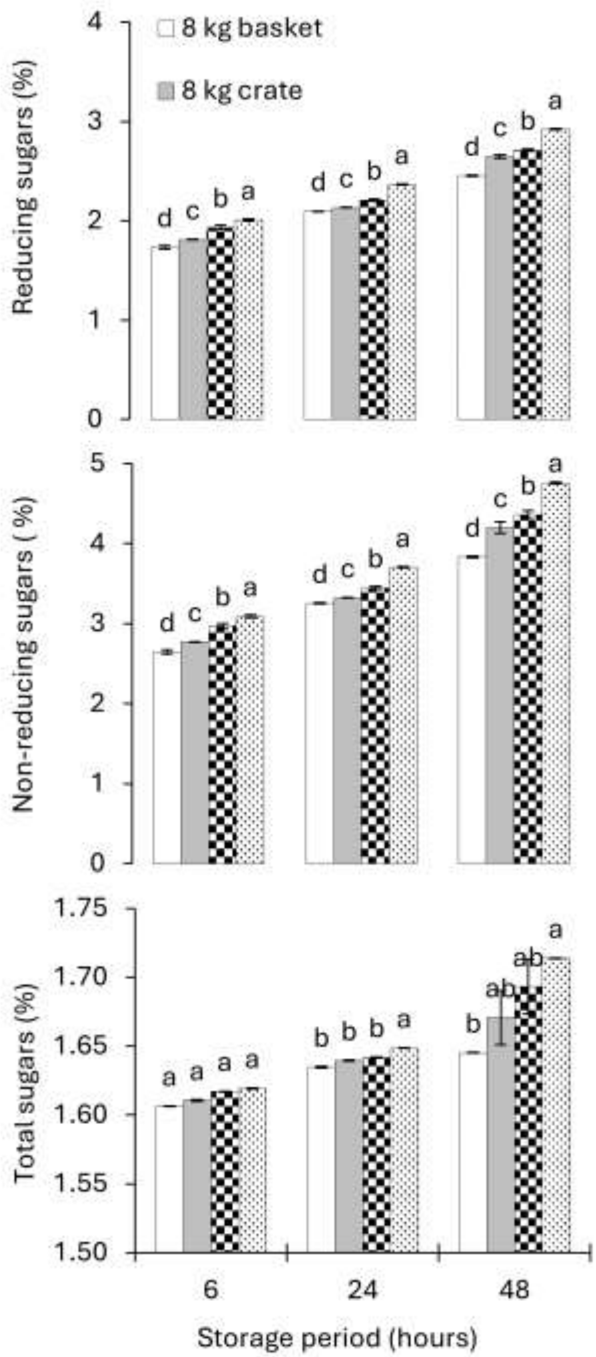

Figure 4: Effect of packaging on reducing sugars, non-reducing sugars and total sugars in strawberry fruit. Vertical bars indicate average ± standard error.

Conclusion

This research was carried out at the Postharvest training and research centre, Institute of horticultural sciences (IHS), University of Agriculture, Faisalabad and the comprehensive result of this study showed that out of four packaging materials the best one was the 360 g plastic punnet. In this packaging shelf life of strawberry was enhanced and other physical and chemicals attributes showed best result. Total soluble solids and titratable acids was well maintained in the fruits of this packaging.

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Conflict of Interest Statement

The authors declare no known competing interests.

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